The Age of a Glacial Erratic Located on the Ohio State University Campus

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Abstract

An age determination was carried out using the Rubidium-Strontium method on a large glacial erratic located at the north-west corner of Orton Hall on the campus of The Ohio State University. In 1905 the rock was moved to its present site from the Columbus Esker. The Columbus Esker located at 16th and Iuka Avenues in Columbus, Ohio is a remnant of the Scioto Lobe of Wisconsin glaciation. The age determination obtained for the boulder is 1.02 billion years. A comparison of this age determination was made with age determinations made on rocks of the Canadian Shield. The rock was found to have come from the Grenville Province. This is consistent with ice flow directions determined for Wisconsin glaciation which indicate that the glacier traveled through the Grenville Province on its way to Ohio.

Acknowledgments

Thanks are due to several people for the help given me in doing this research. Dr. Gunter Faure deserves special thanks for suggesting the topic and for providing much valuable assistance. Thanks are due, also to Roy Carwile, who was able to locate a coring device, and to Dr. Sidney White who found the two Ohio State Lantern articles used in this paper.

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Introduction

This study was carried out to determine the origin of a glacial erratic located at the north-west corner of Orton Hall on the Ohio State University campus. The former location of the boulder was the Columbus Esker which is a remnant of Wisconsin glaciation. To determine the origin of the erratic, its geologic age was determined using the Rubidium-Strontium method. This date was compared with age determinations carried out by the Geological Survey of Canada on rocks from the Canadian Shield.

History of the Boulder

An interesting landmark on the campus of the Ohio State University, Columbus, Ohio is a large boulder located at the northwest corner of Orton Hall at 155 South Oval Drive (Fig. 1).

According to an article in the Ohio State Lantern (Fig.2) the boulder, a large glacial erratic, was originally located at the corner of Sixteenth and Iuka Avenues at the present site of the Wesley Foundation. The article relates the story of John Scatterday who formerly lived at that location. He related in a letter to Dr. Edmund M. Spieker the history of the boulder. Originally, the boulder was almost completely buried. Several times as a youth Scatterday unsuccessfully attempted to dig the boulder out.

Sixty-six years ago in 1905 contact was made with the boulder during construction of Iuka Avenue. The road was rerouted slightly west to avoid the boulder. When the question of a sidewalk arose, Scatterday's parents granted the contractor permission to dig a large hole to the east of the boulder in which to bury it. Before this was accomplished, however, Dr. Edward Orton saw the boulder and made arrangements to have it brought to

Figure 1. A large glacial erratic which is the subject of this study is located at the northwest corner of Orton Hall on the campus of The Ohio State University.

Figure 2. An article from the Ohio State Lantern describing how the boulder was moved from Iuka Avenue to the Ohio State University campus.

Origin Of Rock Explained

Orton Hall Boulder Relic Of Plesiocene Ice Age; Causes Bankruptcy, Law Suits, Speculation

Among the 40 different kinds of stone used in the construction of Orton Hall, none has achieved as much fame as the 30-ton boulder on the lawn near the northwest corner. Many stories and traditions are told and have been written about the stone—the bankruptcy it caused a contractor, law suits and the team of oxen dragging the stone to its present site.

Early this year John Scatterday, ex-'14, addressed a letter to Prof. Edward M. Spieker, department of geology, to establish the location from which the stone came. "Since I am the last witness of its location," Scatterday said, "it would seem only right to straighten out all of the guessing."

Scatterday's old home is the present Wesley Foundation, 16th and Iuka Avenues. Scatterday recalled that as a boy, he often tried to dig out the stone from where it was buried at the edge of his yard with only a foot showing. "The stone's position when found was the same as it now rests in front of Orton Hall," he said.

When excavation for Iuka was started in 1905, contact was made with the stone. Work was stopped and a new curb location was made which pushed the curb farther to the west. When the question of the sidewalk arose, Scatterday's parents granted the contractor permission to bury the stone on their property.

To accomplish this, the contractor was going to bring in a steam shovel and dig a deep hole to the east of the stone, then push the stone in the hole and bury it. This would have cleared the way for paving. It was then that Dr. Edward Orton, first president of the University and professor of geology, saw the stone and made arrangements to have it brought to the University.

The stone is a large erratic boulder of anorthosite, an igneous rock not native to this state. This contrast with the native stone used in Orton Hall makes the stone a "foreigner" in spite of the fact that it has probably been here some 25,000 years. It was carried down from Canada by one of the ancient glaciers during the Pleistocene ice age.

the Ohio State University.

A second Ohio State Lantern article (Fig. 3) tells of the dispute that arose after the boulder was delivered. The contractor after delivering the boulder presented a bill to the Geology Department for moving costs. The Geology Department refused to pay the bill because it had not ordered the boulder to be moved. Instead the department suggested that the rock be removed. The mover, having suffered a broken wagon in bringing the boulder to the college, declined the offer and left the boulder where it is today.

Wisconsin Glaciation

The former site of the glacial erratic on Sixteenth and Iuka Avenues is on the Columbus Esker. The esker was first described by Morse in 1906. It extends in a north-south direction from Iuka Avenue almost to Fifteenth. It is bounded on the east and west by Summit Street and Indianola Avenue respectively (Fig. 4).

Morse described the esker at the site of the excavation for Woodruff Avenue. At this location the esker is 128 feet wide and 16.7 feet high. The bottom layer of 12 inches contains a great number of angular and partly water worn pebbles of the adjacent Ohio Shale. The middle of the esker exhibits a strata that dips twenty to 40 degrees off to either side. Here coarse and fine sand alternate with each other and with layers of coarse and fine gravel. On either side, at the edges, the stratification is somewhat disturbed. At the side the strata contain a few rounded pebbles of the Ohio Shale and neighboring limestone, but the great majority of the rocks are granitic erratics. A thin sheet of till caps the esker.

Fig. 3. An Ohio State Lantern article describing the dilemma that faced the mover of the boulder.

Ohio State's Rocks Haven't Rolled Lately

By Dick Williams

Ohio State's rocks don't roll!

At least, for the past half century they haven't, and according to Prof. Sidney E. White, of the geology department, they're likely to stay where they are.

AT THE TURN of the century, the department of geology acquired a number of curious rocks from various sources. They were placed around the campus for use in connection with geology classes.

"In recent years some of the rocks had to be disposed of due to the heavy construction on the campus," Professor White explained. "But those remaining have remained intact. Though the rocks may seem an open invitation to souvenir hunters and pranksters, we've never had one damaged or moved."

It's easy to see why.

TAKE THE great Glacial Boulder on the northwest lawn of Orton Hall, for example. Even Charles Atlas in his prime wouldn't want to cart it around for any length of time. It is estimated to weigh somewhere between 12 and 15 tons! And several of those tons are embedded firmly in the ground.

This boulder was discovered at the corner of 16th and Iuka Aves., present site of the Wesley Foundation. When excavation for Iuka Ave. began in 1905, workmen hit the rock. The contractor first planned to dig a deep hole and bury it, but instead he arranged for the boulder to be hauled to the University as a gift to the geology department.

Eight fine, sturdy horses tugged and pulled the monstrosity down 15th Ave. to its present location at Orton Hall. The geology department received a bill for transportation of the stone. A squabble arose over the high cost of moving. While the department was grateful for the contribution, it had not ordered the rock and did not feel obligated to pick up the tab.

IN ANSWER to the mover's protests, the department chairman graciously offered the mover the privilege of removing the rock. Wishing to prolong the lives of his horses, the mover declined and the matter was dropped.

Though the boulder has remained stationary for years, in its younger days it was constantly on the move. Oh, not during the past 25,000 years or so, but it once traveled with one of the ancient glaciers during the Pleistocene ice age. It is believed to have been carried down from Canada by one of the glaciers.

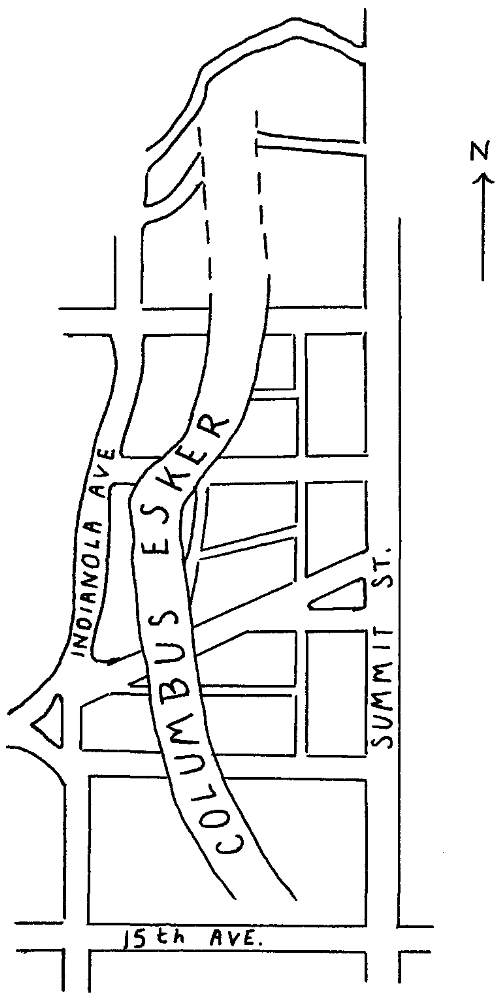
ANOTHER rock, a cylindrically shaped one between Orton and Mendenhall, is known as a sandstone core. Accepting this rock brought no ill-feeling—but after the movers deposited the rock and the geologists were satisfied with its location, someone discovered that it was upside down.

But the department did not insist that the rock be turned around. Someone even noticed that from the top (actually the bottom) impressions of leaves could be seen clearly. Bottom, or top, top or bottom—the department did not quibble.

Today the sandstone core remains upside down.

Figure 4. Map showing the location of the Columbus Esker in Columbus, Ohio.

Modified from Morse (1907).



The Columbus Esker was formed by the Scioto Lobe during the Wisconsin ice advance. Carbon 14 dating has been carried out by Goldthwait (1970) on logs buried in till and gravel deposited by the Scioto Lobe. He has obtained radiocarbon dates of 18,000-23,000 years for different parts of the Scioto Lobe.

Ice flow directions for Wisconsin glaciation in Canada have been determined by the Geological Survey of Canada. The work of the Survey indicates that the ice that covered Ohio originated in the Grenville Province of Ontario and Quebec and moved in a generally westerly to southwestwardly direction paralleling Lake Ontario. Approaching Lake Erie, parts of the glacier assumed a more southerly direction of movement. (Fig. 5) Goldthwait, writing in the Ohio Journal of Science (1959), and Leverett in an earlier paper indicate a generally southerly movement of the glacier in Ohio with local topographically induced variations in its direction.

Moraines, since they are generally largest and best developed at the glacier front, give a good indication of ice flow directions. Moraine patterns illustrated in Figure 6 show that different parts of the Scioto Lobe were moving in easterly, southerly, and westerly directions as the glacier over-rode this topographically low area.

Description of the Erratic

A thin section was made for microscopic examination. Thin section study indicated that the boulder is a grayish-yellow fine to coarse grained leucocratic granodiorite. It consists primarily of anhedral feldspar consisting of oligoclase (45 percent) commonly showing spindle shaped albite twinning and microcline (30 percent). The microcline

Figure 5. General direction of Wisconsin glaciation ice movement in parts of the Grenville and Superior Provinces in Canada.

Modified from: Glacial Map of Canada #1253A : Geological Survey of Canada.
Province boundaries modified from Map 67-2: Geological Survey of Canada.

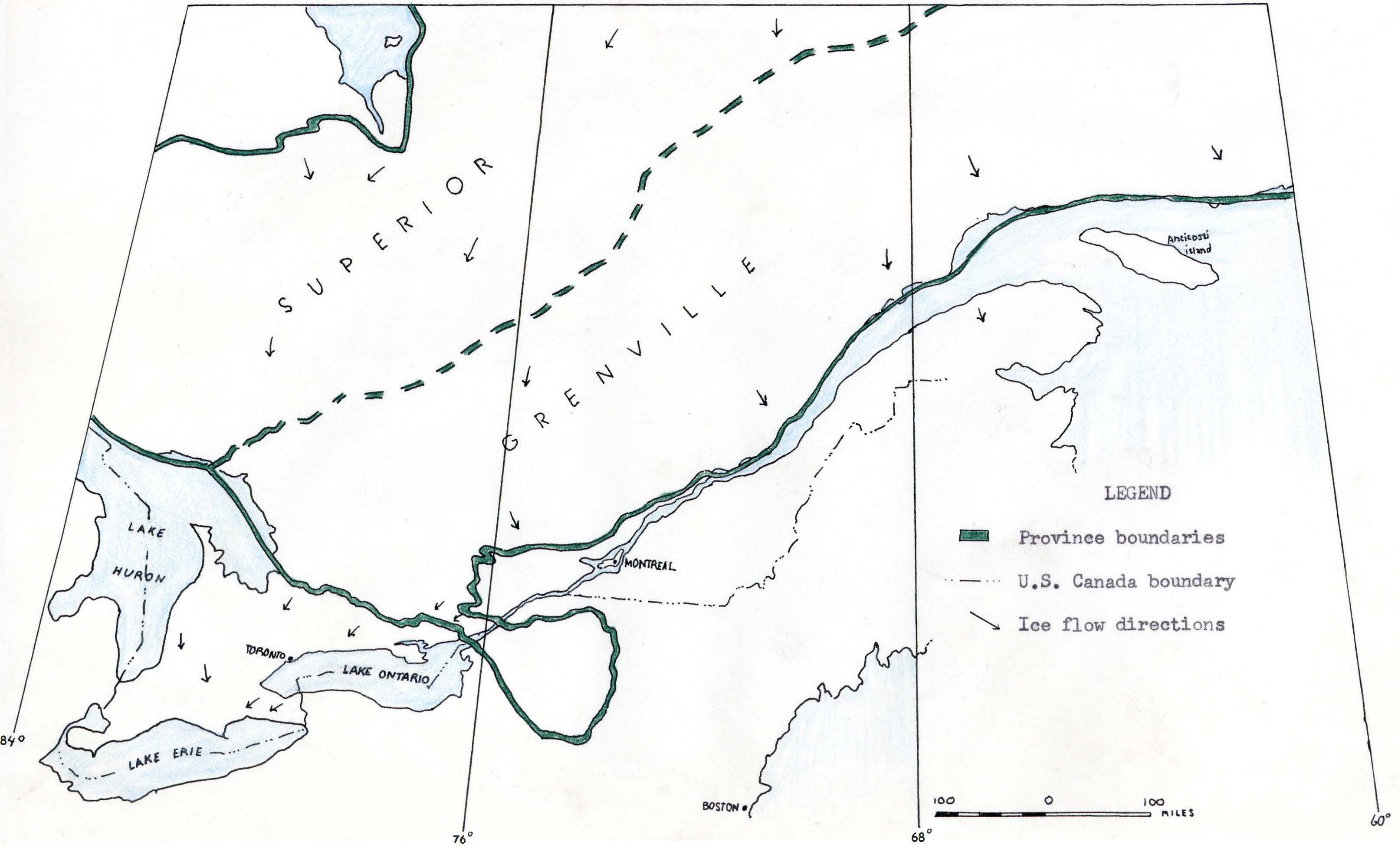
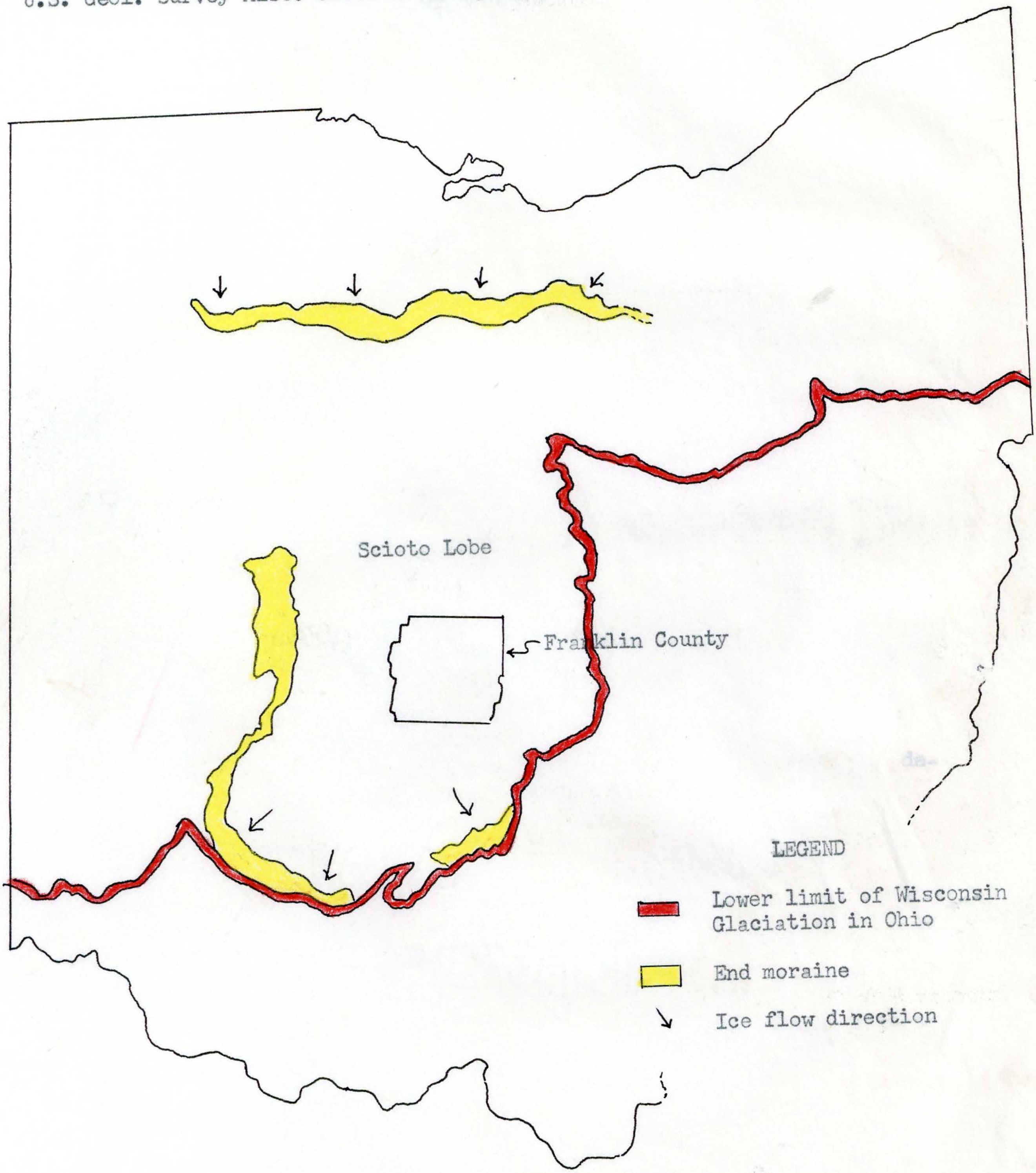


Figure 6. Map showing southern extent of Wisconsin Glaciation in Ohio. Certain end moraines are illustrated to show ice flow directions.

Adapted from Glacial Map of Ohio
U.S. Geol. Survey Misc. Geol. Inv. Map I-316



commonly contains oriented blebs of untwinned plagioclase. Most of the microcline exhibits stress induced undulating extinction. The quartz (15 percent) occurs in three forms. A very small amount of it occurs as large highly shattered anhedral crystals. Most of it occurs with plagioclase in myrmekitic form in interstitial positions and also deeply intergrown in the microcline. The remaining portion of the quartz is granulated and occurs with plagioclase in interstitial areas. The rock contains, also, biotite (5 percent), hornblende (2 percent), epidote (less than 2 percent), clinozoisite (less than 2 percent), and magnetite (1 percent).

The rock appears to have been stressed before complete solidification of the magma. The dark minerals are not evenly distributed through the rock, but are, instead, confined to small areas with the biotite and magnetite closely associated.

Dating by the Rubidium-Strontium Method

In order to compare this erratic with rocks of the Canadian Shield, an age determination was made using the Rubidium-Strontium method. This method utilizes the fact that radioactive Rb^{87} decays to Sr^{87} by beta decay.

The fundamental law of radioactivity is

$$N = N_0 e^{-\lambda t} \qquad (1)$$

where N equals the number of Rb^{87} atoms remaining in the sample, λ is the decay constant of Rb^{87}, t is time, and N_o is the number of Rb^{87} atoms originally present in the sample (Hamilton, 1965).
Subtracting from the original number of Rb^{87} atoms (N_o) the number of Rb^{87} atoms remaining now (N) gives the number of daughter Sr^{87} atoms (D)

formed from radioactive Rb^{87}.

$$D = N_0 - N \tag{2}$$

From equation 1 it follows that

$$N_0 = Ne^{\lambda t}. \tag{3}$$

Thus, the number of daughter atoms of Sr^{87} produced by decay is

$$D = Ne^{\lambda t} - N$$

or

$$D = N(e^{\lambda t} - 1). \tag{4}$$

The total Sr^{87} in the rock now (D_t) is the total of the Sr^{87} originally in the rock (D_o) and the Sr^{87} formed by radioactive decay of Rb^{87} (D).

$$D_t = D_o + D \tag{5}$$

Substituting in equation four for D gives

$$D_t = D_o + N(e^{\lambda t} - 1) \tag{6}$$

or

$$Sr_t^{87} = Sr_o^{87} + Rb^{87}(e^{\lambda t} - 1). \tag{7}$$

Equation seven may be divided by the number of Sr^{86} atoms present in the sample of rock to form the Sr^{87}/Sr^{86} ratio which can be measured directly by means of a suitable mass spectrometer.

$$\frac{Sr^{87}}{Sr^{86}} = \left(\frac{Sr^{87}}{Sr^{86}}\right)_o + \frac{Rb^{87}}{Sr^{86}}(e^{\lambda t} - 1). \tag{8}$$

Equation eight can be solved for t if the Sr^{87}/Sr^{86} and the Rb^{87}/Sr^{86} ratios are measured and a suitable value of the $(Sr^{87}/Sr^{86})_o$ ratio is assumed:

$$t = \frac{1}{\lambda} \log_e \frac{\left(\frac{Sr^{87}}{Sr^{86}}\right) - \left(\frac{Sr^{87}}{Sr^{86}}\right)_o}{\frac{Rb^{87}}{Sr^{86}}} + 1. \tag{9}$$

Analytical Procedures

To obtain an age determination for the boulder, the Sr^{87}/Sr^{86} ratio was measured using a mass spectrometer. A whole rock sample was used on the mass spectrometer.

The sample was obtained by drilling a $1\frac{1}{4}$ " core approximately two inches deep. The interior one-half of the core was crushed until it passed through a 120 mesh screen. The crushed rock was mixed to obtain a uniform mineral distribution by placing it on a sheet of paper and alternately folding the paper in half, first one way and then the other, thirty times. A .5 gram portion of the mixed rock was taken for use on the mass spectrometer.

Several chemical procedures were carried out to render the sample suitable for use. First, the sample was dissolved in sulphuric and hydrofluoric acid on a hot plate. As the sample was evaporated to dryness, the silicon was driven off as SiF_4 gas. The residue was dissolved in about 100 ml. of dilute hydrochloric acid. Subsequently, the volume of the solution was reduced to approximately thirty milliliters and it was allowed to cool to room temperature. After cooling the sample was filtered to remove any crystals or any insoluable material. Six drops of a solution containing radioactive Sr^{89} was added to the solution to act as a tracer.

This sample, along with 300 ml. of hydrochloric acid, was placed on an ion-exchange column to separate the strontium from the other elements (Aldrich, 1952). Individual 15 ml. beakers of the sample were collected at the bottom of the column. These were checked with a Geiger counter to determine which had the highest radioactive content from the Sr^{89} tracer.

From the beaker containing the highest radioactivity a one-half ml. sample for use on the mass spectrometer was taken.

The mass spectrometer used to measure the Sr^{87}/Sr^{86} ratio was a single filament Nier type instrument. To reduce error from non-linear drift, the peaks for the Sr^{87} and Sr^{86} were each added together in sets of six.

Because of fractionation occurring during emission from the filament caused by the difference in the mass of the two isotopes, a correction was made to the measured Sr^{87}/Sr^{86} ratio. To correct for fractionation, the measured Sr^{86}/Sr^{88} ratio was compared with .1194 which is assumed to be the constant Sr^{86}/Sr^{88} ratio for natural strontium (Hamilton 1965). The formula

$$f = \frac{2\,(Sr^{86}/Sr^{88})_m}{(Sr^{86}/Sr^{88})_m + .1194} \qquad (10) \qquad \text{(m=measured)}$$

gives the factor (f) which was multiplied by the measured Sr^{87}/Sr^{86} ratio to correct for fractionation.

The original Sr^{87}/Sr^{86} ratio (($(Sr^{87}/Sr^{86})_o$ in formula 91)) was assumed to be .7040 (Gast 1960).

The Rb^{87}/Sr^{86} ratio was determined using the x-ray fluorescence technique. For use on the x-ray machine some of the whole rock sample was compressed into a pellet. For maximum efficiency with rubidium and strontium, a molybdenum x-ray target was used. the machine was set up with a crystal of lithium fluoride (220) and a .010 soller slit.

The scintillation counts for both the $RbK\alpha$ and $SrK\alpha$ were adjusted for background interference. This was accomplished by subtracting the average of the background interference on either side of the $RbK\alpha$.

This process was repeated for SrKα.

One hundred second counts were made over the rubidium and strontium 2-theta range and their contiguous backgrounds. Five 2-theta positions were used: Background (1) at 34.78 degrees, SrKα at 35.85 degrees, Background (2) at 36.92 degrees, RbKα at 37.99 degrees, and Background (3) at 39.06 degrees.

The average was taken of the RbKα/SrKα ratio.

The standard deviation of the average ratio was calculated using the formula

$$\bar{\sigma} = \sqrt{\frac{\Sigma d^2}{N(N-1)}} \qquad (11)$$

where d is the difference between the average combined RbKα/SrKα ratio and the ratio for the individual counts, and N is the number of runs.

Two corrections were made to the average RbKα/SrKα ratios. One correction was for a decrease in the intensity of the scintillation counts intrinsic to this x-ray apparatus. This correction factor has been worked out by Eastin (1970) as K=1.2895. The second correction was made to adjust the RbKα/SrKα ratio to reflect only the Rb^{87}/Sr^{87} concentration. This correction factor was obtained using the formula

$$C = \left[\frac{N \cdot \text{ABUNDANCE } Rb^{87} \cdot \text{ATOMIC WEIGHT } Sr}{N \cdot \text{ATOMIC WEIGHT } Rb \cdot \text{ABUNDANCE } Sr^{86}}\right] \qquad (12)$$

where the N's which are Avogadros' number cancel. The abundance of Rb^{87} in common rubidium is 27.85 percent (Nier, 1950). The atomic weight of strontium is 87.62. For rubidium, the atomic weight is 85.47 while the abundance of Sr^{86} used for this experiment is .0987 (Bainbridge & Nier, L950).

Inserting this data into formula 12 gives

$$C = \frac{.2785 \cdot 87.62}{85.47 \cdot .0987} = 2.892 \qquad (13)$$

which, when multiplied by the correction worked out by Eastin, gives

$$1.2895 \cdot 2.892 = 3.729. \qquad (14)$$

Multiplying the 3.729 by the average $RbK\alpha/SrK\alpha$ gives the corrected Rb^{87}/Sr^{86} ratio.

The Age Determination

The Sr^{87}/Sr^{86} ratio was measured on a Nuclide Corpporation, Model 6-60-S mass spectrometer. The average of 23 sets to determine the Sr^{87}/Sr^{86} was .71347. This ratio was multiplied by the correction for fractionation (f) in formula 10 which was found to be

$$f = \frac{2(.11877)}{(.11877) + .1194} = .99735 \qquad (15)$$

which gives

$$.99735 \cdot .71347 = .7116 \qquad (16)$$

the corrected Sr^{87}/Sr^{86} ratio.

Fifteen runs were made to determine the Rb^{87}/Sr^{86} ratio using the x-ray fluorescence technique on a General Electric XRD 6. The average $RbK\alpha/SrK\alpha$ ratio corrected for background radiation (Fig. 7) was

$$2.1300/15 = .1420 \qquad (17)$$

Multiplying this number by the correction factor worked out in calculation 14 gives

$$.1420 \cdot 3.729 = .5296 \qquad (18)$$

the corrected Rb^{87}/Sr^{86} value.

The standard deviation of the RbK /SrK ratio of the fifteen runs (Figure 8) is

$$\bar{\sigma} = \sqrt{\frac{5292 \times 10^{-8}}{15(14)}} = \pm .0005 \qquad (19)$$

The decay constant λ has been determined by Aldrich (1956) to by $1.39X10^{-11}$.

The insertion of the calculated values into formula 9 gives:

$$t = \left(\frac{1}{1.39 \times 10^{-11}}\right) \ln e \left(\frac{.7116 - .7040}{.5296} + 1\right) \qquad (20)$$

$$= \left(\frac{1}{1.39 \times 10^{-11}}\right) 2.303 \log_{10} (1.01435)$$

$$= \left(\frac{1}{1.39 \times 10^{-11}}\right) 2.303 (.00618)$$

$$= \frac{.01423}{1.39 \times 10^{-11}}$$

$$t = 1.023 \times 10^{9} \text{ year} \pm 5\%.$$

Figure 7. Correction of x-ray fluorescence scintillation counts of SrKα and RbKα for background radiation

Set Number	Gross Count SrKα	Background Radiation $\frac{B_1+B_2}{2}$	Net Count SrKα	Gross Count RbKα	Background Radiation $\frac{B_1+B_2}{2}$	Net Count RbKα	Net Ratio $\frac{RbK\alpha}{SrK\alpha}$
1	19286	4029	15257	5593	3400	2193	.14374
2	18952	3815	15137	5478	3337	2140	.14140
3	19038	3725	15312	5402	3157	2244	.14657
4	18704	3527	15177	5262	3107	2154	.14195
5	18802	3431	1 5370	5135	2927	2208	.14365
6	19156	4324	14831	5752	3685	2067	.13936
7	19238	4264	14973	5801	3680	2121	.14165
8	19266	4260	15006	5728	3651	2076	.13837
9	19175	4176	14999	5731	3606	2125	.14167
10	19324	4156	15168	5706	3566	2139	.14105
11	19181	4094	15087	5681	3541	2140	.14184
12	19213	4045	15167	5635	3478	2156	.14217
13	19129	3994	15134	5614	3445	2168	.14328
14	19236	3946	15289	5567	3388	2179	.14251
15	19205	3896	15309	5528	3380	2148	.14030
							2.1300

Figure 8. Computation of the deviation (d) and d^2 for each of the RbK /SrK ratios obtained from 15 runs with the x-ray fluorescence technique.

Run Number	Average RbK /SrK ratio for 15 runs	RbK /Srk	$d x 10^{-4}$	$d^2 x 10^{-8}$
1	.1420	.1437	17	289
2	.1420	.1414	6	36
3	.1420	.1466	46	2116
4	.1420	.1420	0	0
5	.1420	.1437	17	289
6	.1420	.1394	26	676
7	.1420	.1417	3	9
8	.1420	.1384	36	1296
9	.1420	.1417	3	9
10	.1420	.1411	9	81
11	.1420	.1418	2	4
12	.1420	.1422	2	4
13	.1420	.1433	13	169
14	.1420	.1425	5	25
15	.1420	.1403	17	289
				$5292 x 10^{-8}$

Thus the time elapsed since the rock crystallized from magma is 1.023 billion years plus or minus five percent.

Comparison of Age Determinations

A comparison of the age determination for this boulder and age determinations of rocks from the structural provinces in Canada indicates that it came from the Grenville Province. The Geologic Survey of Canada has subdivided Canada into structural provinces. The Survey has determined the geologic age of many rocks in these provinces. In the Grenville Province (Fig. 5) which has its western edge north of Lake Erie and trends in a northeasterly direction, the common age determination has been found to be about one billion years. Age determinations for rocks of the Superior Province which lies to the north of the Grenville Province and extends westward to the Province of Manitoba indicate that these rocks are about 2.5 billion years old. Since the age determination ascertained for this boulder agrees with age determinations for rocks of the Grenville Province, it suggests that this boulder came from the Grenville Province.

Conclusion

The glacial erratic now located on the Ohio State University campus is a granodiorite that was formerly located at the Columbus Esker. The Columbus Esker was formed by the Scioto Lobe of Wisconsin glaciation that occurred eighteen thousand to twenty three thousand years ago. An age determination of the rock made by the use of the Rb-Sr method indicate that it has a geologic age of 1.023 billion years. A comparison of this age determination with age determinations carried out by the Geological Survey of Canada indicate that the boulder was originally located in the Grenville Province in Canada. The assumption, made on the basis of age determinations, that this boulder came from the Grenville Province is consistent with known directions of ice movement for Wisconsin glaciation.

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